6-1972

A comparative study of the characteristics of "mini" layers and a conventional layer

Charles D. Leeper

To the Graduate Council:

I am submitting herewith a thesis written by Charles D. Leeper entitled "A comparative study of the characteristics of "mini" layers and a conventional layer." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Husbandry.

H.V. Shirley Jr, Major Professor

We have read this thesis and recommend its acceptance:

J.K. Bletner, R.L. Tugwell, R.R. Shrode

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

14 3

May 1972

To the Graduate Council:

I am submitting herewith a thesis written by Charles D. Leeper entitled "A Comparative Study of the Characteristics of 'Mini' Layers and a Conventional Layer." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Poultry.

H. V. Shirley
Major Professor

We have read this thesis
and recommend its acceptance:

Robert R. Shrode

J. K. Bletner

R. L. Tugwell

Accepted for the Council:

Hilton A. Smith
Vice Chancellor for
Graduate Studies and Research

A COMPARATIVE STUDY OF THE CHARACTERISTICS OF "MINI" LAYERS AND A CONVENTIONAL LAYER

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

---

by

Charles D. Leeper

June 1972

ACKNOWLEDGEMENTS

With deep appreciation the author wishes to acknowledge the direction and assistance of the following:

Dr. H. V. Shirley, Jr., Poultry Department, for serving as committee chairman and for supervision, guidance, and encouragement during the course of graduate study, and preparation of the manuscript.

Dr. J. K. Bletner, Poultry Department, for serving on the graduate committee, for counsel and guidance during the course of graduate study, and for reviewing the manuscript.

Dr. R. L. Tugwell, Head of the Poultry Department, for serving on the graduate committee, for encouragement during the course of study, and for reviewing the manuscript.

Dr. R. R. Shrode, Animal Husbandry Department, for serving on the graduate committee, for counsel given, and for reviewing the manuscript.

Dr. O. E. Goff, former Head of the Poultry Department, for all the assistance and encouragement during the early part of graduate study.

To all the members of the Poultry Department staff for their assistance.

Mrs. Barbara Myers, for typing this manuscript.

The author wishes to express a special thanks to his family, especially his wife, Carol; their encouragement throughout the author's period of graduate study was extremely helpful.

TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

LIST OF FIGURES

INTRODUCTION

The poultry industry is a rapidly changing industry. In the past few years many changes in all phases of the industry, including breeding, management, processing and marketing have been made. One of the most significant changes has been the high density housing of layers. An important factor in determining optimum bird density in a house is body size. A hen of small body size offers several possible advantages. These include: a better feed efficiency, less space requirement per bird and less manure to dispose of. The main disadvantage is that small body size is generally associated with reduced egg production and reduced egg size. Another disadvantage is that the salvage value of the spent hen is less. In some cases processors do not like to handle the smaller birds because of the low yield.

There are basically two ways of breeding a small hen that will lay an egg of acceptable size. One method involves selection of chickens that are small, but lay large eggs. The second method involves the use of a dwarf gene that is recessive and sex-linked. The dwarf gene, *dw*, reduces body size by approximately 25 to 30 percent. Stocks that have been produced by these methods are considerably smaller in body size as compared to conventional stocks. They have been variously referred to as "mini", "midget" or "dwarf" chickens.

Hutt's (1949) observations provided the stimulus for much of the earlier research with mini layers. Bernier and Arscott (1960) stimulated much of the present interest when they published a report of work done at Oregon State University. Since that time commercial poultry breeders have accepted the challenge of producing a marketable "mini" layer. At present there exists much interest and controversy about mini layers and their performance.

OBJECTIVE

The objective of this study was to compare the performance of several stocks of "mini" layers with that of a conventional layer when maintained at various cage densities.

LITERATURE REVIEW

The effects of the recessive sex-linked dwarf gene, dw, were observed by Hutt (1949). According to this researcher, this gene reduced the body size of females about 30 percent at maturity, while, in males, the reduction in body size was as much as 42 percent. The effects of the dw gene were not noticeable at the time of hatching. By the age of 8 to 10 weeks some of the dwarf chickens could be identified. The most accurate identification could be made at the age of 4 to 6 months. The chickens carrying the gene dw matured sexually, and both sexes reproduced normally. Hutt stated that the dw gene is different from the recessive autosomal dwarf gene td.

The recessive sex-linked gene dw has no noticeable effect on hatchability as reported by Hutt (1959). This gene retarded growth from two weeks of age. Egg production also was reduced 7.9 to 13.3 percent below that of normal sisters and half-sisters. The egg size was 4.8 to 6.5 grams smaller. Shank length was markedly reduced. Hutt stated that the dwarf gene, dw, is remotely linked to the barring gene (B) and shows crossover of 6.6 percent with the slow feathering gene (K) and 7.0 percent with the silver gene (S) and that the probable order of these genes in the chromosome is B-S-K-dw.

Body weight and egg weight are controlled by both independent and pleiotropic genes. This was demonstrated by

Festing and Nordskog (1967) by selection work in four lines of Leghorns originating from a common source. Selection was based on measurements made at approximately 32 weeks of age. The trends in the heritability values were not statistically significant, but both phenotypic and genetic correlation declined significantly over generations.

Lowering body weight by 0.1 kilograms from the over-all mean of 1.5 kilograms can be expected to increase hen-housed egg production by 12 eggs and decrease the age at maturity by 4 days on the genetic scale, but to decrease egg production by 18 eggs and increase maturity by 14 days on the environmental scale as reported by Nordskog and Briggs (1968). The genetic scale was said to reflect body size while the environmental scale was said to reflect body condition or fleshing. Relatively speaking, condition was said to be more important in determining productivity than body size.

By feeding Protamone to mini layers and normal layers, Rajaratnam et al. (1969) demonstrated that the small body size and low feed intake of dwarf chickens may be due in part to a low thyroxine secretion.

Selvarajah et al. (1970) noted some interesting points about sex-linked dwarf layers when fed 19 percent protein and high energy rations, and 16 percent protein and low energy rations. Egg production and egg size were both lower in dwarf layers than in normal layers. Feed utilization was better in the dwarf birds, however. The results supported the evidence reported by Rajaratnam *et al*. (1968), previously cited, that thyroxine plays an important role in the manifestation of dwarfism. This work also supports Jaap's (1969) suggestion that in addition to depressing protein anabolism, there may be reduced lipoprotein production in the liver and consequently depression of yolk formation.

Quisenberry *et al*. (1969) demonstrated that neither protein level nor cage density influenced body weight of hens fed 16 percent and 17 percent protein diets and housed in densities of 1, 2 and 3 birds per cage. Egg production of both normal and mini layers was lowest at the density of three per cage. Egg size of the mini layers was slightly increased by feeding 17 percent protein, but both 16 percent and 17 percent protein diets produced smaller eggs in mini layers than in normal layers (54.4 grams versus 60.2 grams). Hen-day percent production was 52.2 for the mini layers and 69.1 for the normal layers. Further research indicated that higher protein levels, up to 22 percent, increased egg number and size, improved feed efficiency and improved livability of mini layers, while only egg size and feed efficiency were improved in the normal layers.

Magruder and Coune (1969) compared one mini stock to two normal stocks of S.C.W. Leghorns during 21 to 65 weeks of age. The use of five diet programs demonstrated some of the characteristics of mini layers. The diet programs were: (1) reducing total protein from 21 percent to 14 percent, (2) 18 percent to

16 percent, (3) 18 percent to 16 percent protein with additional vitamins, (4) 16 percent for the entire period and (5) 16 percent protein with added energy after 41 weeks of age. In all five treatments the mini layer had about 20 to 30 percent lower hen day egg production. In all but treatment 2, the mini layer showed a more efficient use of feed per dozen eggs. The egg weights in grams at 37 weeks of age were 51 for the mini, and 57 and 56 for the two normal stocks. At 57 weeks of age the egg weights in grams were 61, 62 and 63, respectively.

Bernier and Arscott (1960) concluded that dwarf hens weighed 63 percent as much and consumed 66 percent as much feed as their normal sisters. Dwarf females matured sexually at a later age than normal sisters and laid 18 percent fewer eggs that weighed 10 percent less per dozen. The dwarf layers required 74 percent as much feed per dozen eggs and 84 percent as much feed per 24 ounces of eggs. Shells of the eggs produced by dwarf hens were thinner than shells of the egg produced by normal sisters. Also Cage Layer Fatigue appeared to be more of a problem in dwarf layers.

Arscott _et al_. (1961) noted that egg weight was not influenced by any dietary treatment given to dwarf and normal chickens used in their research. Specific gravity values of eggs were improved by high calcium and phosphorus levels (3.0 to 0.9 percent compared to 2.3 to 0.6 percent) for both dwarf and normal layers. The specific gravity of the eggs of the dwarf hens was lower than that of normal hens, but was improved more by the high calcium-phosphorus level. Egg production increased 5 percent in normal hens and 15 percent in dwarf hens that were fed the high calcium-phosphorus level. Protein levels of 15.7 percent and 18 percent resulted in 18-19 percent less feed being consumed at the high level. Lower production was noted in the normal birds, but not in the dwarfs receiving the 18 percent protein diet. Observations were made during the growing period by Bernier and Arscott (1966) on two populations, one from dwarf males mated to normal size females and the other from all normal-sized stock. The chickens were fed a diet containing 20.9 percent protein and 1370 kilocalories of metabolizable energy per pound from 3 to 8 weeks of age, and 14.9 percent protein and 1285 kilocalories per pound from 8 to 23 weeks of age. Feed conversion favored the dwarfs throughout the growing period. The first egg was produced during the 19th week in both populations, but the dwarf pullets reached 25 percent production at 25 weeks of age compared to 23 weeks for the normal sized pullets.

The difference in feed required to produce eggs of two adjacent sizes amounted to 1.756 grams per egg or 4.3 percent of the weight of the egg as found by Bird and Sinclair (1939a). Due to the volume of feed required to maintain body weight, the smallest bird giving maximum production of a standard sized egg is, economically, the most desirable unit according to these workers.

Work by Bird and Sinclair (1939b) indicated that the weight of feed consumed is positively and significantly correlated to the body weight to be maintained, weight of the eggs produced and changes in body weight. According to these workers, the requirements for maintenance depends on the rate of metabolism. Chickens with a high metabolism rate have a high requirement for maintenance. In somatically immature birds the efficiency of feed utilized purely for egg production is about 75 percent. Through the remainder of the biological year this efficiency is reduced to about 60 percent. The storing of reserves actively inhibits the formation of eggs, and reserves are drawn upon slightly in support of egg production. Total weight of the weekly egg production is independent of body size.

Statistics developed from more than 50,000 laying hens on a northern California egg laying enterprise during the period from June 1968 to April 1969 as published in the Northern California Poultry Letter (October 1969), revealed some of the following insights about mini layers. The small hens required about 53 percent of the amount of feed required by the larger hens and only about 73 percent of the feed required by larger hens to produce a dozen eggs. The feed per dozen eggs was 3.13 pounds for mini layers and 4.31 pounds for the conventional layers. Percent egg production was 52.9 for the mini layer and 70.2 for the conventional layer from 31 to 66 weeks of age.

The <u>dw</u> gene appears to eliminate some of the defective eggs laid by broiler-type pullets as observed by Jaap and Mohammadian (1969). The sex-linked recessive dwarf gene was found to reduce the rate of yolk deposition, but not the rate of production. This indicated to these workers that dw has an effect on protein anabolism.

In earlier work Jaap (1969) observed that broiler-type pullets laying at 56 percent production had more ovarian follicles in rapid development than did Leghorns laying at a level of 84 percent production. The broiler-type pullets' ovaries were reported to produce yolks actually more rapidly than their oviducts could form eggs. According to Jaap, the dw gene slows the rate of yolk production and this phenomenon is detrimental to the egg-type Leghorn, but actually helps the broiler to produce better quality eggs. The body size of the dam was reduced by as much as 30 percent by the dw gene without reducing the growth rate of the broiler chicks she produced. This was said to make it possible to reduce the cost of production and maintenance of the breeder flock.

MATERIALS AND METHODS

Experimental Stock

The eggs of each of the four "mini" stocks and those of the conventional stock were obtained from breeders and hatched in the University of Tennessee incubators at the poultry research farm. It was indicated by several of the breeders that their mini stocks were experimental and that they preferred that the stocks be coded by number or letter. As a consequence all stocks will be referred to only by number throughout this thesis.

Of the four mini stocks used in the research, three were carriers of the sex-linked recessive gene dw. These stocks are identified by numbers 1, 2 and 4. The most obvious distinctions between these and normal layers were shorter shank length and reduced body size. Stock number 5 was assumed to be a stock that had been selected for small body size. The shank length of the mature birds was the same as that of conventional stock number 3, but body size was reduced. Stock number 1 has not been produced for commercial purposes, but stocks 2, 4 and 5 are experimental stocks that may be marketed commercially in the future.

Analysis of Data

The data were analyzed by analysis of variance and where there were significant differences between treatments, a multiple range test as outlined by Duncan (1955) was used to identify particular significant differences between means.

Care of the Chickens

Sexing, debeaking and vaccination against Newcastle and infectious bronchitis diseases were performed at one day of age. Chicks of all five stocks were brooded in the same house but in separate pens. The pens were 14' 10" x 9' 4" in dimensions and provided approximately 0.58 square feet of floor space per chick. A regular vaccination schedule was followed with respect to Newcastle disease, infectious bronchitis and fowl pox. Body weights were obtained at about four-week intervals thru the age of 20 weeks. Standard diets, as shown in Table 1, were fed during the brooding and growing period. A 21.9 percent protein diet was fed thru eight weeks of age, and a 17.2 percent protein diet was fed from nine thru twenty weeks.

The pullets were moved to laying cages at 140 days of age. Each stock was housed in cages of three different sizes (8 x 16 inch, 10 x 16 inch and 12 x 16 inch) at rates of 1, 2 and 3 birds per cage. It was intended that those in 8-inch cages have four replications per rate per stock; those in 10-inch cages three replications per rate per stock and those in 12-inch cages, two replications per rate per stock. Due to error at the time of housing, however, certain stocks did not have the desired number of replications. In order to utilize most efficiently the facilities available, the number of cages varied depending on the rate per cage. For example, replicates housed at a rate of one bird per cage had six birds with six cages involved, while those housed at a rate of two birds per

TABLE 1

DIET FORMULATION

Feedstuff	Starting diet	Growing diet	Laying diet
	%	%	%
Yellow corn	63.600	71.875	66.975
Alfalfa meal, 17% protein	2.500	5.000	5.000
Fish meal	2.500	2.500	2.500
Vitamin mix[a]	.600	.600	.500
Defluorinated rock phosphate	1.500	1.500	1.500
Ground limestone	.600	1.000	6.000
Salt	.480	.500	.500
Manganese sulfate	.020	.025	.025
Soybean meal, 50% protein	22.500	14.500	17.000
Coccidiostat premix	2.500	2.500	.000
	100.000	100.000	100.000
Calculated to contain:			
Crude protein, %	21.94	17.18	16.75
Productive energy, C/kg.	2077.43	2139.11	2017.95
C/P (Calorie:protein ratio)	43.80	56.60	56.70
Metabolizable energy C/kg.	2930.00	2967.44	2800.01
Metabolizable energy C/P ratio	60.70	78.40	75.90
Methionine, %	0.408	0.336	0.327
Cystine, %	0.313	0.261	0.253
Calcium, %	0.960	1.126	3.026
Phosphorus, %	0.692	0.645	0.633
Available phosphorus, %	0.449	0.435	0.431
Manganese, mg./kg.	68.736	79.242	79.088
Vitamin A, I.U./kg.	11783.847	17557.91	15691.969
Vitamin D, I.C.U./kg.	749.020	749.02	2956.426
Riboflavin, mg./kg.	6.631	6.785	4.935
Niacin, mg./kg.	61.200	61.354	44.280
Pantothenic acid, mg./kg.	14.694	14.386	11.522
Choline, mg./kg.	1581.754	1324.003	1338.323

[a] Mineral and vitamin content calculated to equal or exceed requirement as given by National Research Council.

cage had six birds with three cages and those with a housing rate of three birds per cage had six birds with two cages. The laying ration shown in Table 1 (page 13) was fed during the remainder of the experiment.

Methods of Data Collection

Egg size distribution was determined by weighing the eggs from each replicate on a gram scale one day of each week from twenty-one weeks of age thru sixty-eight weeks. The eggs were then candled and graded by size on the basis of the weight classes according to the standards in the USDA Egg Grading Manual (1969).

Egg quality was determined on eggs from each replicate one day of each twelve week period of the forty-eight week laying period. The eggs were weighed on gram scales to obtain an average egg weight. They were then submerged in salt solutions of differing concentrations as shown in Table 2 to determine shell thickness by the specific gravity method. The eggs were then broken out to determine Haugh units and to examine the interior for meat and blood spots. The Haugh units were determined by the use of a tripod micrometer with average egg weights used in the calculations. These examinations were made during December 1969, February 1970, May 1970, and July 1970.

The feed cost was calculated on the basis of the cost of the ingredients plus $5.00 per ton for mixing. Calculated in this way the starter-grower diet price was $4.01 per cwt. The

TABLE 2

SALT WATER CONCENTRATIONS FOR SPECIFIC GRAVITY DETERMINATIONS

Specific gravity		Code of score
1.068	Floaters	0
1.072	Floaters	1
1.076	Floaters	2
1.080	Floaters	3
1.084	Floaters	4
1.088	Floaters	5
1.092	Floaters	6
1.096	Floaters	7
1.100	Floaters	8
	Sinkers	9

laying diet price was $3.47 per cwt. The average amount of feed consumed per chicken was multiplied by the proper feed price to give the average feed cost per chicken.

The pounds of feed per dozen eggs was determined by dividing the pounds of feed consumed by the number of dozens of eggs produced by each replication. The pounds of feed required to produce one pound of eggs was determined in a similar manner.

The first date on which each replicate of six birds laid two eggs on each of two consecutive days was considered as the age of 33 1/3 percent production. This percent production was chosen because of the low rate of lay of some of the stocks.

The returns per bird housed were calculated by multiplying the number of dozens of each egg size category by the price for that size. All categories were then added together and divided by 6. Prices were based on the Chicago market as reported by Federal-State Market News Service in Atlanta, Georgia. The prices per dozen were determined to be 27.4 cents for pee wee, 33.8 cents for small, 40.2 cents for medium, and 46.6 cents for large, extra large and jumbo.

Income over feed cost for six birds was determined in the same manner as the returns per bird except the feed cost was subtracted from the egg value instead of dividing it by 6.

The percent hen housed production was determined by dividing the total production by the total possible hen days. In order to allow for mortality, the percent hen day production was determined by dividing the total production by the tctal actual hen days. A hen day is defined as one hen being present for one day.

RESULTS AND DISCUSSION

Growing Period

The body weights and feed conversions taken at intervals during the growing period are presented in Table 3.

The pounds of feed required per pound of gain for stock number 2 was considerably less than for stocks 1, 3, 4 and 5 thru the 20 weeks. The other mini birds were comparable in this trait to the conventional stock thru 20 weeks of age.

The body weights of stocks 1, 2 and 4 were smaller than those of stocks 3 and 5 thru the 9th week. At the 14th week only stocks 1 and 4 were smaller than the conventional stock. Stocks 2 and 5 were slightly heavier than the conventional stock at the 14th week. At 20 weeks of age all mini stocks had a smaller body weight than the conventional stock, with stock number 4 being the lightest in weight.

Egg Size Distribution

The analyses of variance of the data pertaining to egg size distribution are presented in Table 4. Significant differences among stocks occurred in each of the six egg size categories. These differences, as determined by the use of Duncan's multiple range test, are shown in Table 5. Stock number 3, the conventional size layer, produced a higher percentage of the larger eggs than did the mini stocks. With the exception of the medium category, there were significant

TABLE 3

FEED CONVERSIONS AND AVERAGE BODY WEIGHTS OF MINI STOCKS AND A CONVENTIONAL STOCK DURING THE GROWING PERIOD

Age	Stock no.				
	1	2	3[a]	4	5
5 weeks					
Lbs. feed/lb. gain	2.25	2.04	2.30	2.40	2.70
9 weeks					
Lbs. feed/lb. gain	3.45	2.68	2.99	3.11	2.99
Av. body weight (lbs.)	1.01	1.07	1.37	0.95	1.40
14 weeks					
Lbs. feed/lb. gain	4.19	3.44	4.19	3.68	3.59
Av. body weight (lbs.)	1.46	1.66	1.64	1.38	1.95
20 weeks					
Lbs. feed/lb. gain	4.54	4.22	4.58	4.61	4.60
Av. body weight (lbs.)	2.22	2.17	2.58	1.96	2.34

[a] Conventional stock.

TABLE 4

OVERALL ANALYSES OF VARIANCE OF EGG SIZE DISTRIBUTION OF THE EGGS PRODUCED BY FIVE STOCKS MAINTAINED AT THREE HOUSING RATES IN EACH OF THREE CAGE SIZES

Source of variation	d.f.	Size distribution (%)					
		Pee wee m.s.	Small m.s.	Medium m.s.	Large m.s.	Extra large m.s.	Jumbo m.s.
Stock (S)	4	7.77*	962.26**	105.78*	429.21**	382.45**	1.61*
Cage size (C)	2	0.01	22.50	11.51	30.82	143.36	0.62
Rate per cage (R)	2	1.02	6.61	46.62	112.38	8.26	0.35
S x C	8	2.97	67.43*	23.69	65.11	29.81	0.96
C x R	4	3.10	27.31	22.44	22.39	65.40	0.83
S x R	8	3.40	35.86	29.14	72.24	16.83	1.13
S x C x R	16	1.37	42.70	55.27	111.45*	76.31	0.87
Error	90	2.37	29.66	33.66	55.89	62.05	0.67

* $P \leq 0.05$

** $P \leq 0.01$

TABLE 5

MEAN VALUES OF EGG SIZE DISTRIBUTION OF THE EGGS PRODUCED

Source of variation	Size distribution (%)					
	Pee wee	Small	Medium	Large	Extra large	Jumbo
The mean values of egg size distribution by five stocks (all treatments combined).						
Stock						
1	1.54^{a}	18.65^{a}	27.92^{a}	40.72^{c}	11.05^{c}	0.12^{c}
2	$0.53^{b,c}$	14.02^{b}	28.46^{a}	$43.39^{b,c}$	$13.45^{b,c}$	$0.15^{b,c}$
3	0.16^{c}	5.83^{d}	23.53^{b}	50.24^{a}	19.68^{a}	$0.59^{a,b}$
4	$1.20^{a,b}$	20.04^{a}	$26.30^{a,b}$	41.22^{c}	10.95^{c}	$0.28^{a,b,c}$
5	$0.37^{b,c}$	9.91^{c}	$25.83^{a,b}$	$46.48^{a,b}$	$16.67^{a,b}$	0.69^{a}
The influence of rate per cage on egg size distribution (all stocks and cage sizes combined).						
Birds per cage						
1	0.93	14.22	26.50	43.70	14.40	0.27
2	0.70	13.76	25.02	46.28	14.02	0.38
3	0.70	13.59	27.67	42.96	14.44	0.43
The influence of cage size on egg size distribution (all stocks and cage rates combined).						
Cage size						
8" x 16"	0.77	13.68	26.07	44.06	14.33	0.44
10" x 16"	0.79	14.65	26.34	45.08	12.82	0.30
12" x 16"	0.78	13.02	25.79	43.77	16.87	0.29

Mean values in the same column which are followed by different superscripts are significantly different ($P \leq 0.05$).

differences among the mini stocks in all of the egg size categories. The two stocks producing the highest percentages of pee wee eggs and the lowest percentages of large eggs were both carriers of the dw gene.

Neither cage size nor the number of birds per cage had any significant influence on egg size distribution. Of the two way interaction mean squares only stock x cage size for the percentage small eggs produced was significant. Figure 1 shows these relationships. Stocks 2 and 5 produced more small size eggs when housed in 10" x 16" cages than when housed in the other two cage sizes. Stock 4 was the only one of the five stocks producing a higher percentage of small eggs when housed in 12" x 16" cages.

The three way interaction of stocks x cage size x rate per cage was significant ($P \leq 0.05$) for the percent of large eggs. No attempt was made to identify the mean values responsible for the interaction, however.

Egg Quality

The analyses of variance for the egg quality traits are presented in Table 6. Highly significant differences ($P \leq 0.01$) were shown between stocks for the traits of specific gravity, Haugh units and egg weight. Significant differences ($P \leq 0.05$) were indicated among stocks for the percentage of blood and meat spots. These differences are shown in Table 7. Significant differences ($P \leq 0.05$) were found among the mini stocks for all egg quality traits. Stock number 3, the conventional

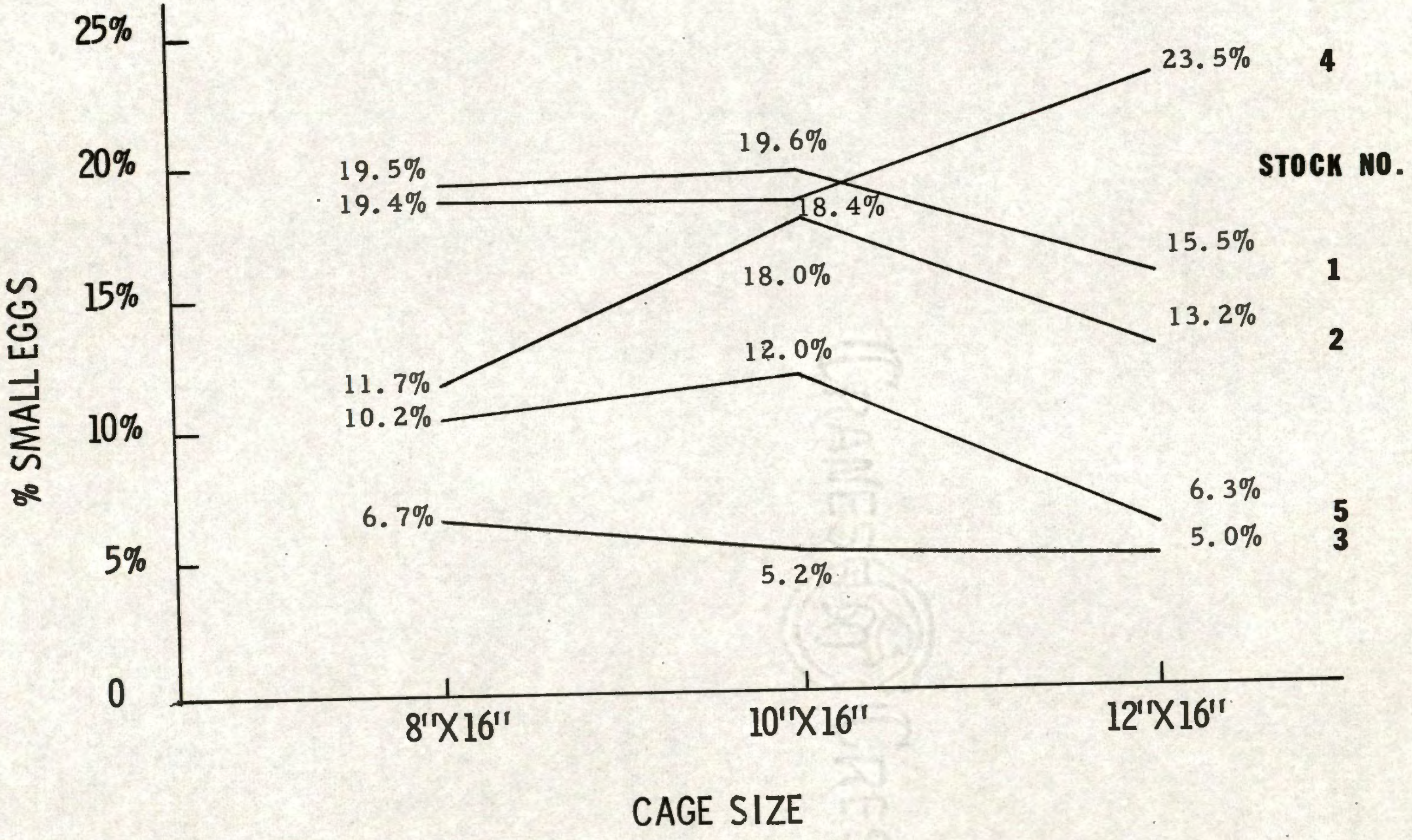

Figure 1. The percent small eggs produced by five laying stocks maintained in cages of three sizes.

TABLE 6

OVERALL ANALYSES OF VARIANCE FOR EGG QUALITY AND FEED EFFICIENCY OF FIVE STOCKS MAINTAINED AT THREE HOUSING RATES IN EACH OF THE THREE CAGE SIZES

		Egg quality				Feed efficiency	
Source of variation	d.f.	% blood and meat spots m.s.	Specific gravity score m.s.	Haugh units m.s.	Egg weight (grams) m.s.	Pounds of feed per dozen eggs m.s.	Pounds of feed per pound of eggs m.s.
Stock (S)	4	6.41*	1.26**	157.72**	42.04**	11.15**	6.66*
Cage size (C)	2	3.16	0.42	64.15	5.48	0.71	0.45
Rate per cage (R)	2	4.12	0.13	30.12	1.79	2.82	1.41
S x C	8	2.35	0.27	29.78	3.21	1.84	0.77
C x R	4	1.31	0.43	20.34	2.12	2.32	1.18
S x R	8	5.00*	0.87**	12.66	1.43	0.64	0.28
S x C x R	16	1.62	0.31	10.55	2.71	1.17	0.63
Error	90	1.88	0.28	29.97	2.64	1.14	0.52

* $P \leq 0.05$

** $P \leq 0.01$

TABLE 7

MEAN VALUES OF EGG QUALITY AND FEED EFFICIENCY

Source of variation	Egg quality				Feed efficiency	
	% blood and meat spots	Specific gravity score	Haugh units	Egg weight (grams)	Pounds of feed per dozen eggs	Pounds of feed per pound of eggs
The mean values of egg quality and feed efficiency of five stocks (all treatments combined).						
Stock						
1	1.48^{a}	3.70^{a}	75.56^{b}	55.66^{c}	5.76^{a}	3.93^{a}
2	$0.66^{a,b}$	$3.32^{b,c}$	76.52^{b}	57.05^{b}	4.63^{b}	3.07^{b}
3	$0.67^{a,b}$	3.13^{c}	75.11^{b}	58.72^{a}	4.25^{b}	2.74^{b}
4	$0.79^{a,b}$	$3.56^{a,b}$	80.77^{a}	$56.21^{b,c}$	5.38^{a}	3.63^{a}
5	0.40^{b}	$3.36^{b,c}$	79.31^{a}	58.08^{a}	4.45^{b}	2.90^{b}
The influence of rate per cage on egg quality and feed efficiency (all stocks and cage rates combined).						
Birds per cage						
1	1.09	3.43	76.58	57.06	4.82	3.20
2	0.82	3.48	78.16	57.40	4.69	3.10
3	0.50	3.35	77.82	56.89	5.25	3.50
The influence of cage size on egg quality and feed efficiency (all stocks and cage rates combined).						
Cage size						
8" x 16"	1.08	3.49	78.50	57.13	4.85	3.22
10" x 16"	0.92	3.30	76.64	56.81	5.07	3.38
12" x 16"	0.58	3.45	76.90	57.55	4.81	3.17

Mean values in the same column which are followed by different superscripts are significantly different ($P \leq 0.05$).

laying stock, had the lowest numerical specific gravity score and lowest numerical Haugh unit score of all the stocks. This could probably be related to the higher rate of production of the conventional stock. The average weights of eggs of stocks 3 and 5 significantly ($P \leq 0.05$) were greater than those of the other stocks.

The interaction mean squares between stocks x rate per cage for the percentage blood and meat spots and specific gravity scores was significant ($P \leq 0.05$). The multiple range test indicated that stock number 1 had a higher incidence of blood and meat spots when placed in 12" x 16" cages at the rate of 3 birds per cage than did other stocks subjected to any of the treatments. The other stocks had a smaller percent blood and meat spots in 12" x 16" cages compared to the other size cages.

The interaction between stocks x rate per cage for the specific gravity scores was significant ($P \leq 0.01$) but the specific interaction was not identified.

Feed Efficiency

The analyses of variance for the feed efficiency traits are shown in Table 6 (page 24). Highly significant differences ($P \leq 0.01$) between stocks occurred for both traits. These differences are shown in Table 7 (page 25). The conventional stock, number 3, had the most efficient utilization of feed, but was closely followed by stock number 5 which did not carry the dw gene. These two stocks, it may be pointed out, had the highest rate of egg production. Stocks 2, 3 and 5 were not significantly different ($P \leq 0.05$). The mini stocks showed significant differences ($P \leq 0.05$) for both of the feed efficiency traits.

Cage size and number of hens per cage did not significantly influence the pounds of feed required to produce a pound of eggs or a dozen eggs. None of the interaction other mean squares were significant ($P \leq 0.05$) for these traits.

Production

The analyses of variance for the data of the production traits are presented in Table 8. Highly significant differences ($P \leq 0.01$) among stocks occurred for each of the four traits: percent hen-housed production, percent hen-day production, total production of six birds and age at 33 1/3 percent production. The means for these traits are shown in Table 9. The conventional stock, number 3, excelled in respect to all four of these traits. Stock number 5 laid at a higher rate of production than did the remaining three stocks which were carriers of the dw gene. Stock number 4 reached 33 1/3 percent production at a significantly older age as compared to the four other stocks.

The analyses of variance of production traits given in Table 8 show that significant differences existed with respect to rate per cage, for hen housed production and for total production of six birds but not for hen day production. The mean values, as shown in Table 9, reveal that for both these

TABLE 8

OVERALL ANALYSES OF VARIANCE FOR PRODUCTION TRAITS OF FIVE STOCKS MAINTAINED AT THREE HOUSING RATES IN EACH OF THREE CAGE SIZES

		Production			
Source of variation	d.f.	% hen housed m.s.	% hen day m.s.	Total of six birds m.s.	Days to 33 1/3 % m.s.
Stock (S)	4	3,291.32**	3,460.01**	1,535,598.66**	906.83**
Cage size (C)	2	41.09	126.33	19,170.06	241.99*
Rate per cage (R)	2	389.23**	174.94	181,596.16*	110.35
S x C	8	28.93	96.78	13,498.49	26.96
C x R	4	39.19	69.23	18,286.05	25.45
S x R	8	44.31	38.84	20,905.62	42.78
S x C x R	16	27.09	71.19	12,637.95	48.78
Error	90	29.40	70.30	13,716.15	65.12

* $P \leq 0.05$

** $P \leq 0.01$

TABLE 9

THE MEAN VALUES OF PRODUCTION TRAITS OF FIVE STOCKS MAINTAINED AT THREE HOUSING RATES IN EACH OF THREE CAGE SIZES

Source of variation	Production			
	% hen housed	% hen day	Total of six birds	Days to 33 1/3 %
The mean values of production traits of five stocks (all treatments combined).				
Stock				
1	36.84^{e}	39.32^{d}	795.63^{e}	167.52^{b}
2	48.30^{c}	50.65^{c}	1,043.24^{c}	165.84^{b}
3	64.06^{a}	68.35^{a}	1,383.67^{a}	161.30^{c}
4	40.57^{d}	43.47^{d}	876.37^{d}	177.37^{a}
5	57.46^{b}	59.56^{b}	1,241.04^{b}	167.73^{b}
The influence of rate per cage on production traits (all stocks and cage sizes combined).				
Birds per cage				
1	51.00^{a}	52.57	1,101.58^{a}	166.31
2	51.29^{a}	54.05	1,107.94^{a}	168.76
3	45.19^{b}	49.42	976.00^{b}	169.52
The influence of cage size on production traits (all stocks and cage rates combined).				
Cage size				
8" x 16"	48.42	53.25	1,045.88	169.70^{a}
10" x 16"	49.69	50.38	1,073.40	168.31^{b,a}
12" x 16"	50.04	52.13	1,080.80	165.00^{b}

Mean values in the same column which are followed by different superscripts are significantly different ($P \leq 0.05$).

traits the rate of 3 birds per cage resulted in a significantly ($P \leq 0.05$) lowered production rate while cage size made little difference. This would lead one to believe that adverse social reactions increase as the number of birds per cage increased, whereas, cage space per bird, within the limits of this experiment, is not as important. Cage size did influence the age to 33 1/3 percent production. The stocks in 12" x 16" cages had a significantly ($P \leq 0.05$) shorter period to 33 1/3 percent production than did the stocks in 8" x 16" cages. There was more available floor space, feeder space and water trough per bird in the larger cages and, thus, very likely, a more rapid growth of the pullets during the beginning phase of production.

None of the interaction mean squares show significant differences ($P \leq 0.05$) for the four production traits.

Income

The analysis of variance for the traits of income over feed cost and income per bird housed are presented in Table 10. Highly significant ($P \leq 0.01$) sources of variation for both of these traits were stocks and rate per cage. The differences as determined by Duncan's multiple range test are shown in Table 11. Stock number 3, the conventional stock, ranked higher for both income over feed cost and returns per bird housed than any of the mini stocks. The two stocks that had the highest income were both stocks that did not carry the dw gene. The three remaining stocks differed significantly with respect to both traits.

TABLE 10

OVERALL ANALYSES OF VARIANCE OF INCOME, BODY WEIGHT AND PERCENT MORTALITY OF FIVE STOCKS MAINTAINED AT THREE HOUSING RATES IN EACH OF THREE CAGE SIZES

Source of variation	d.f.	Income (dollars) Over feed cost m.s.	Income (dollars) Per bird housed m.s.	Body weight (gms.) At 20 weeks age m.s.	Body weight (gms.) At 68 weeks age m.s.	% mortality m.s.
Stock (S)	4	46.07**	32.67**	692,962.64**	1,498,078.85**	1,015.95**
Cage size (C)	2	0.41	0.76	12,821.05	46,717.49	202.64
Rate per cage (R)	2	6.02**	6.66**	6,050.14	51,642.10	422.99
S x C	8	0.83	0.12	2,274.90	26,092.05	548.31**
C x R	4	1.16	0.35	5,802.14	23,025.07	210.38
S x R	8	0.71	0.20	5,644.34	33,509.82	316.38
S x C x R	16	0.58	0.07	4,134.14	20,667.21	150.38
Error	90	0.60	0.51	4,330.82	18,608.83	191.92

* $P \leq 0.05$

** $P \leq 0.01$

TABLE 11

MEAN VALUES OF INCOME, BODY WEIGHT AND PERCENT MORTALITY

Source of variation	Income (dollars) Over feed cost	Income (dollars) Per bird housed	Body weight (gms.) At 20 weeks age	Body weight (gms.) At 68 weeks age	% mortality
The mean values of income, body weight, and percent mortality of five stocks (all treatments combined).					
Stock					
1	2.51^{d}	4.66^{e}	925.56^{c}	$1,509.59^{c}$	$12.35^{a,b}$
2	3.93^{c}	6.21^{c}	948.72^{c}	$1,519.32^{c}$	8.67^{b}
3	5.71^{a}	8.52^{a}	$1,211.37^{a}$	$1,858.15^{a}$	17.28^{a}
4	2.91^{d}	5.12^{d}	810.27^{d}	$1,227.73^{d}$	17.22^{a}
5	4.87^{b}	7.51^{b}	$1,142.08^{b}$	$1,692.00^{b}$	4.49^{b}
The influence of rate per cage on income, body weight, and percent mortality (all stocks and cage sizes combined).					
Birds per cage					
1	4.15^{a}	6.59^{a}	1,017.71	1,576.04	9.26
2	4.24^{a}	6.66^{a}	996.89	1,565.72	11.59
3	3.46^{b}	5.84^{b}	994.61	1,517.98	15.91
The influence of cage size on income, body weight, and percent mortality (all stocks and cage rates combined).					
Cage size					
8" x 16"	3.91	6.27	1,014.17	1,578.17	13.89
10" x 16"	3.92	6.42	1,002.11	1,547.44	10.00
12" x 16"	4.09	6.51	982.40	1,513.80	12.22

Mean values in the same column which are followed by different superscripts are significantly different ($P \leq 0.05$).

None of the interaction mean squares showed significant ($P \leq 0.05$) differences nor did cage size have any significant effect. When the number of birds per cage was increased to three, it was shown that birds housed at the rate of three birds per cage had a significantly lower income over feed cost and return per bird housed than birds housed at the rate of one or two birds per cage.

Body Weights

The analyses of variance of the data pertaining to body weights are presented in Table 10 (page 31). Highly significant differences ($P \leq 0.01$) are shown to exist among stocks for weights at 20 weeks of age and at 68 weeks of age. The mean values with differences as determined by Duncan's multiple range test are shown in Table 11 (page 32). The conventional stock, number 3, was the heaviest stock at both 20 weeks of age and 68 weeks of age. Both the conventional stock and stock number 5, neither of which carry the dw gene, were significantly ($P \leq 0.05$) heavier than the mini stocks. There were significant differences between some of the mini stocks at both ages.

No significant ($P \leq 0.05$) differences were observed with respect to cage size, rate per cage or any of the interaction effects. The three mini stocks that carried the dw gene were about 27 percent smaller than the conventional stock at 20 weeks of age and 24 percent smaller at 68 weeks of age. Stock number 5 was only 6 percent smaller at 20 weeks of age and 9 percent smaller at 68 weeks of age than the conventional size stock.

Percent Mortality

The analysis of variance of percent mortality is presented in Table 10 (page 31). There were highly significant ($P \leq 0.01$) differences among stocks. The mean values and differences, as determined by the use of Duncan's multiple range test, are shown in Table 11 (page 32). The conventional stock, number 3, suffered the highest percentage mortality. This difference was significant when compared to two of the four mini stocks. The larger body size of stock number 3 might be a factor in this higher mortality rate, but, apparently, body size is not the sole factor involved. Stock number 4 had next to the highest percentage mortality even though it had the smallest body size of all stocks. Prolapse appeared to be more prevalent as a cause of death in stock number 3 than in other stocks. Otherwise specific causes of mortality were not associated with stocks, cage size or rate per cage.

Neither cage size nor number of birds per cage had a significant influence on the percentage of mortality when all stocks were considered together. The fact that percentage mortality did not increase uniformly as cage size decreased and that percentage mortality did increase as the housing rate per cage increased indicated that the stress of social interactions is more affected by increasing number of birds per cage than by decreasing space per bird.

Of the interaction effects only the stock x cage size showed any significances ($P \leq 0.05$). Figure 2 shows these re-

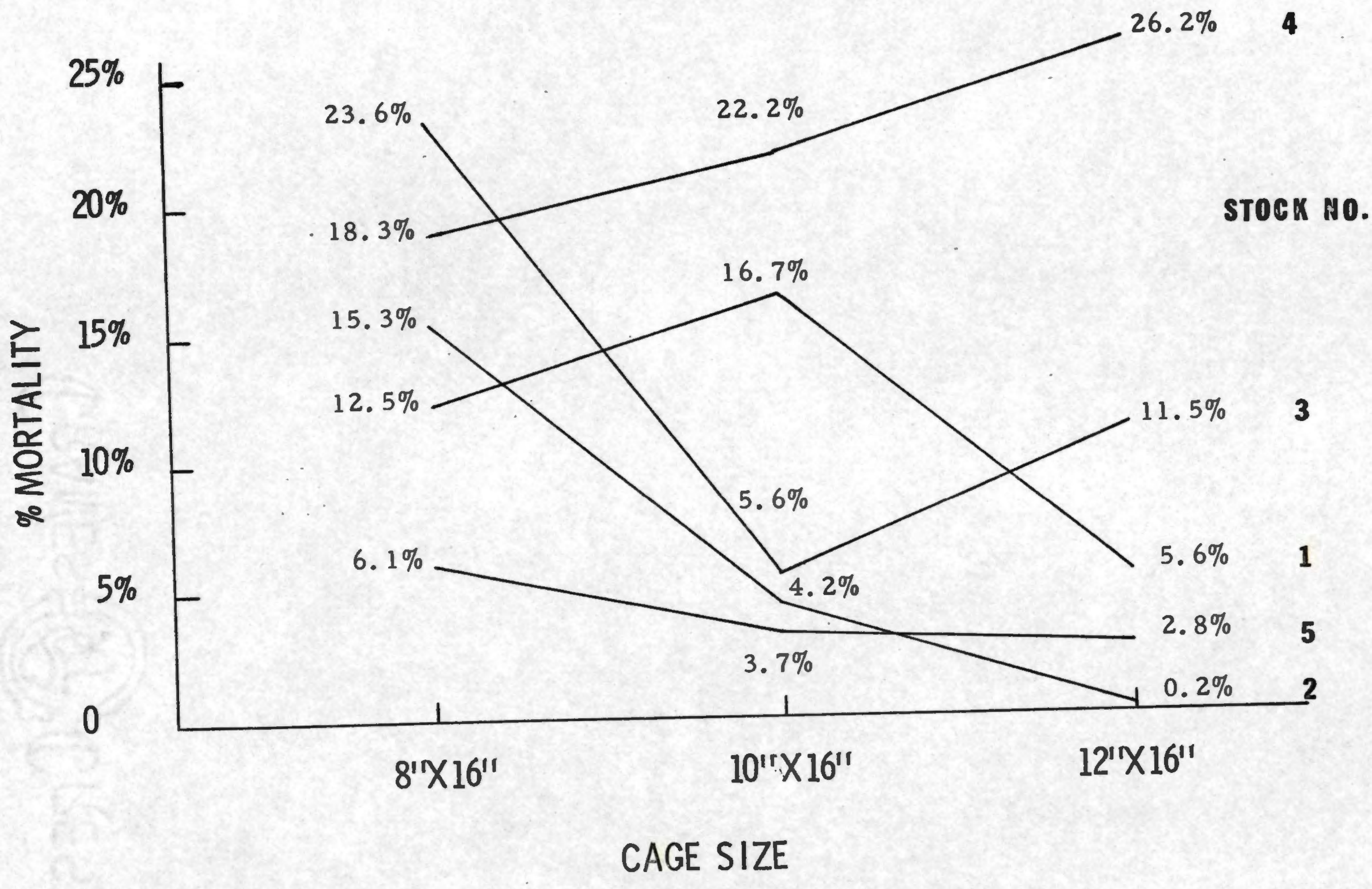

Figure 2. The percent mortality of five stocks maintained in cages of three sizes.

lationships. Stock number 4 had a higher percent mortality in the 12" x 16" cages than in either of the other cage sizes. The highest percentage mortality for stock number 1 occurred in the 10" x 16" cages while the highest percentages of mortality for the other stocks were in the 8" x 16" cages. This may be interpreted to mean that the optimum cage size has to be determined for each individual stock.

SUMMARY

A study was conducted to compare the performance from one day to 68 weeks of age of four "mini" stocks and a conventional stock. Three of the "mini" stocks were carriers of the dwarfing gene dw while the fourth stock was the result of selection for reduced body size but did not carry the dw gene. The conventional stock had a body size typical of that of most commercial layers.

At sexual maturity each stock was housed in laying cages of 8, 10 and 12 inches in width at the rate of 1, 2 and 3 birds per cage.

Measurements taken included: body weights, feed consumption, age at sexual maturity, mortality, rate of egg production, egg size and egg quality.

The dw gene resulted in an average of 27 percent reduction in body size at 20 weeks of age and an average of 24 percent at 68 weeks of age when compared to the conventional stock. Birds of the mini stock produced by selection for small body size were 6 and 9 percent smaller than birds of the conventional stock at 20 and 68 weeks of age, respectively. The growth patterns of the five stocks during the 20 week growing period were dissimilar. The pounds of feed per pound of gain during the growing period did not generally seem to be affected by the presence or absence of the dw gene.

Significant differences among the stocks were found with respect to all traits measured during the laying period. The mini layers, as compared to the conventional layers, required more days to reach sexual maturity, had a lower rate of egg production, produced eggs with a smaller average egg size and with a higher quality based upon shell thickness and Haugh units, required more feed to produce a unit of eggs, had less mortality and produced less income per bird.

Cage size had no significant effect with the exception that one of the mini stocks produced a significantly higher percentage of small eggs when housed in 12" x 16" cages. In addition, differences in cage size resulted in a significant difference in the age at sexual maturity. Birds housed in 12" x 16" cages reached sexual maturity at an earlier age than those housed in 8" x 16" cages. Also, there was a significant interaction between stocks and cage size with respect to mortality, indicating that cage size did influence mortality rate in at least one of the tested stocks.

The number of hens per cage did not have a significant effect upon the age at sexual maturity, egg size, egg quality, feed efficiency or mortality. However, pullets housed three per cage laid at a significantly lower rate and produced a significantly lower income per bird than those housed either one or two per cage. There were also significant interactions between stocks and number of hens per cage with respect to percent blood and meat spots produced and the specific gravity scores, indicating that the rate per cage did influence these traits.

The performance of the mini stock selected for small body size in general was more similar to that of the conventional stock than to the three stocks carrying the dw gene.

REFERENCES

REFERENCES

Arscott, G. H., P. Rachapaetayakom and P. E. Bernier, 1961. Observations on gross requirements for certain nutrients in dwarf white leghorn hens. Poultry Science 40:1372-1373.

Bernier, P. E., and G. H. Arscott, 1960. Relative efficiency of sex-linked dwarf layers and their normal sisters. Poultry Science 39:1235.

Bernier, P. E., and G. H. Arscott, 1966. Growth and feed requirements of dwarf white leghorn pullets as compared to their normal-sized sisters. Poultry Science 45:1070.

Bird, S., and J. W. Sinclair, 1939a. Economic aspects of poultry keeping in Canada with special reference to egg production. Scientific Agriculture 19:551-564.

Bird, S., and J. W. Sinclair, 1939b. A study of the energy required for maintenance, egg production, and changes in body weight in the domestic hen. Scientific Agriculture 19:542-550.

Duncan, D. B., 1965. Multiple range and multiple F tests. Biometrics 11:1-42.

Festing, M. F., and A. W. Nordskog, 1967. Response to selection for body weight and egg weight in chickens. Genetics 55:219-231.

Hutt, F. B., 1949. Genetics of the Fowl. McGraw-Hill Book Company, Inc.

Hutt, F. B., 1959. Sex-linked dwarfism in the fowl. Journal of Heredity 50:209-221.

Jaap, R. G., 1969. Large broilers from smaller hens. World's Poultry Science Journal 25:140-143.

Jaap, R. G., and M. Mohammadian, 1969. Sex-linked dwarfism and egg production of broiler dam. Poultry Science 48:344-346.

Magruder, H. D., and F. L. Coune, 1969. Effect of different diet programs on the performance of midget layers. Poultry Science 48:1838.

Nordskog, A. W., and D. M. Briggs, 1968. The body weight egg production paradox. Poultry Science 47:498-504.

Northern California Poultry Letter, October 1969. As printed in Colonial News and Views, Pleasant Hill, Missouri. July 1970. P. 4.

Quisenberry, J. H., A. Gonzalez Delfino, and J. W. Bradley, 1969. Effects of density and dietary protein level on performance of midget versus normal layers. Poultry Science 48:1861.

Rajaratnam, G., T. Selvarajah and J. D. Summers, 1969. The effects of Thyroprotein on growth rate of dwarf pullets. Poultry Science 48:1768-1770.

Selvarajah, T., F. N. Jerome, J. O. Summers and B. S. Reinhart, 1970. Some effects of sex-linked dwarfism in layer-type fowls. Poultry Science 49:1142-1144.

U. S. Department of Agriculture, 1969. Egg Grading Manual. Agriculture Handbook No. 75.

VITA

Charles D. Leeper was born in Mt. Auburn, Illinois, on December 23, 1943. He attended the Mt. Auburn Community Unit School system through high school. In September 1962 he entered Southern Illinois University, receiving a Bachelor of Science in Agriculture in June, 1966. He subsequently taught vocational agriculture at Kansas High School, Kansas, Illinois, for three years. He entered The University of Tennessee Graduate School, July 1969, as an "Assistant in Poultry." In June 1972, he was granted a Master of Science in Poultry. He is a member of Gamma Sigma Delta.

He is married to the former Carol Ann Breeden of Effingham, Illinois, and has a son, John Lewis, and a daughter, Rebecca Lynn.